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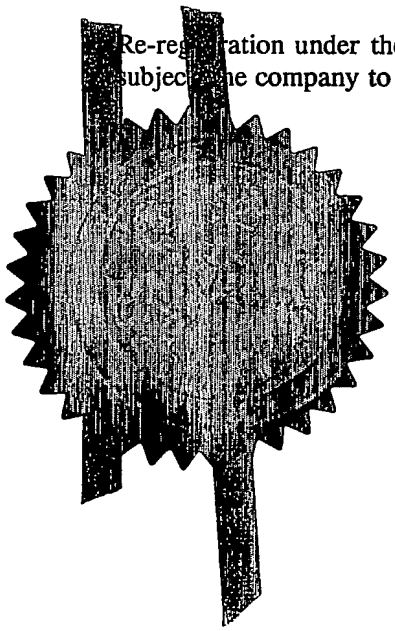

Signed 

Dated 22 October 2003

Patents Form 1/77

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

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Cardiff Road
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1. Your reference

TJF/SK/38037

2. Patent application number
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0222932.6

04OCT02 E753054-1 D00022
P01/7700 0.00-0222932.6

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Flight Refuelling Limited
Brook Road
Wimborne
Dorset BH21 2BJ
United Kingdom

Patents ADP number *(if you know it)*

8385880001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

Battery Conservation

5. Name of your agent *(if you have one)*

fJ Cleveland

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

40-43 Chancery Lane
London WC2A 1JQ

Patents ADP number *(if you know it)*

07368855001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

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Continuation sheets of this form	-
Description	17
Claim *(s)*	-
Abstract	-
Drawing *(s)*	2

10. If you are also filing any of the following, state how many against each item.

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature fJCleveland — fJ Cleveland — Date 3 October 2002

12. Name and daytime telephone number of person to contact in the United Kingdom — Mr T J Faulkner — 020 7405 5875

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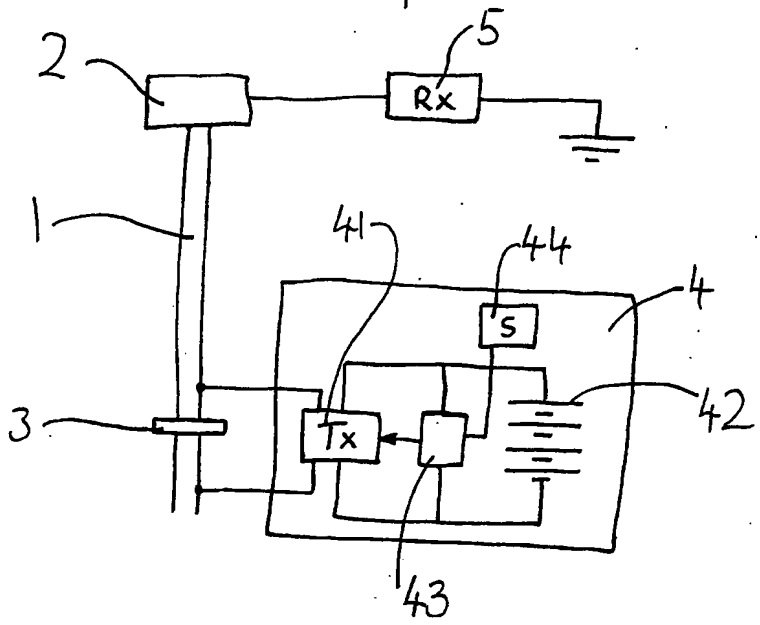
2
5
Rx
1
41
44
4
S
42
3
Tx
43

FIG. 1

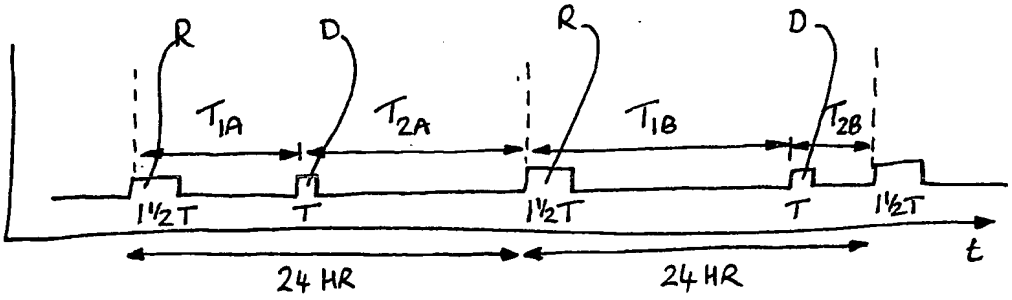
R
D
R
D
T1A
T2A
T1B
T2B
1½T
T
1½T
T
1½T
t
24 HR
24 HR

FIG. 2

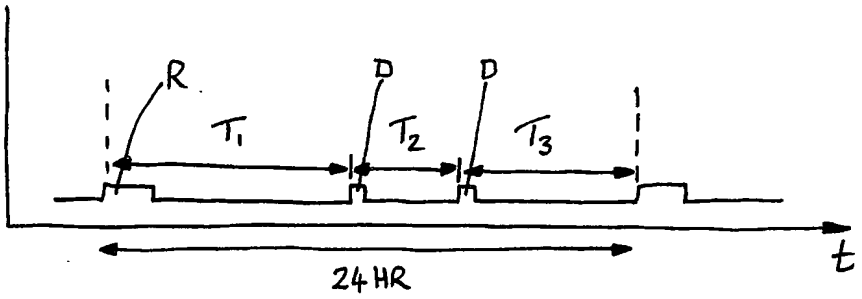

FIG. 3

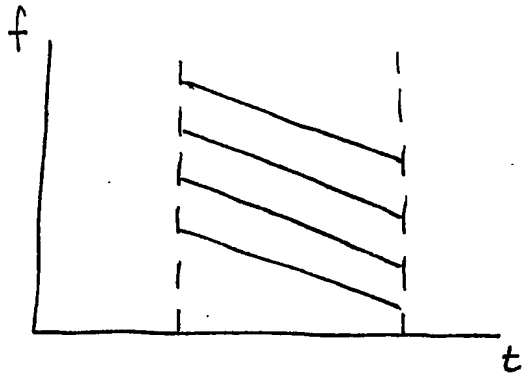

FIG. 4

Battery Conservation

This invention relates to battery conservation in data transmission systems.

In some circumstances the conservation of battery energy in data transmission systems becomes of importance.

A particular area where this is of concern is in the field of pipeline, and particularly downhole communications. In these situations the power demands for transmission can be relatively high compared with the capacity of batteries which can be used. Particularly in downhole circumstances, the types of batteries which can be used and the expense of these batteries is influenced by the environment in which they must survive and operate. These factors lead to it being desirable to conserve battery energy where possible. Furthermore, in the case of some installations, particularly downhole, the replacement of used batteries can be difficult, impossible or not cost effective. In some cases, when the batteries powering a tool have run down, the tool as a whole will have to be replaced.

In other circumstances it will be desired to increase the distance over which signals can be transmitted rather than prolonging battery life. Again, in these

circumstances, systems which effectively conserve battery energy are useful since the power used in transmitting any one set of data might be increased to increase range without adversely affecting the life of the battery compared with a less efficient data transmission system.

It is an object of this invention to provide methods, systems and apparatus which conserve battery energy whilst transmitting data.

According to one aspect of the present invention there is provided a method of conserving battery energy used for transmitting signals carrying data in a transmission system where a predetermined set of data is to be transmitted once during a predetermined period, the method comprising the steps of:

transmitting at least one signal during said period to transmit the set of data;

selecting the time of transmission of said at least one signal; and

representing at least some of the data to be transmitted in terms of the time of transmission of said at least one signal.

According to another aspect of the present invention there is provided data transmission apparatus using battery energy for transmitting signals carrying data in a regime where a predetermined set of data is to be transmitted once during a predetermined period, the apparatus comprising:

transmitting means arranged for transmitting at least one signal during said period to transmit the set of data, and control means for selecting the time of transmission of said at least one signal and arranged for representing at least some of the data to be transmitted in terms of the time of transmission of said at least one signal.

Using such techniques, the overall time spent actually transmitting signals, in order to transmit the set of data, can be minimised. Hence the amount of battery power used in transmitting the set of data can be minimised. In effect time is being used as a resource.

Typically the transmission system will be such that a set of data is to be transmitted once during each of a plurality of successive predetermined periods, which may be contiguous. For example a set of data may be transmitted once every 24 hours.

In some cases there will be a plurality of sets of data, each of which are to be sent once during the same predetermined period or respective predetermined periods. In such cases signals having different frequency characteristics may be used to carry respective sets of data such that the signals are distinguishable from one another.

In one set of embodiments the method comprises the step of transmitting a first, reference, signal within each predetermined period and transmitting at least one further signal, as a data signal, at a selectable time relative to the reference signal within each predetermined period. In such embodiments the time spacing between the signals can be used to represent data. The reference signal may be sent at a preset time in each period, this may for example be the beginning or end of each period.

In one particular case, where there is one data signal in each predetermined period, the time period between the data signal of one predetermined period and the reference signal of the same period may be considered together with the time period between the data signal of that predetermined period and the reference signal of an adjacent period and a ratio of these two time periods used to give a value representing at least some of the data to be transmitted. Where there are a plurality of data signals in each time period, a plurality of ratios may be used and each of these may be used to encode data.

The reference signals may be made distinguishable from the data signals, for example the duration of the signals themselves may differ.

Typically data will be represented digitally and, for example, the predetermined

period may be quantized appropriately such that different timings represent different digital values.

The method may comprise the further steps of:

determining the data size of the predetermined set of data;

determining the transmission characteristics of the channel over which the data is to be transmitted; and

selecting at least one of:

1) the number of signals to send during the predetermined period;

2) the duration of each signal;

3) the power of each signal; and

4) the quantization of the predetermined period,

so as to allow transmission of the required data during the predetermined period whilst minimising the battery energy used.

The apparatus, of course, may be arranged to carry out each of the methods defined above.

The apparatus may comprise computer means.

According to another aspect of the present invention there is provided a

computer program comprising code portions which when loaded and run on computer means cause the computer means to execute the steps of:

a) obtaining information regarding the data size of a predetermined set of data to be sent over a channel during a predetermined period, which set of data is to be sent using the steps of transmitting at least one signal during said period, selecting the time of transmission of said at least one signal, and representing at least some of the data to be transmitted in terms of the time of transmission of said at least one signal;

b) obtaining information regarding the transmission characteristics of the channel over which the data is to be transmitted; and

c) selecting at least one of:

1) the number of signals to send during the predetermined period;

2) the duration of each signal;

3) the power of each signal; and

4) the quantization of the predetermined period,

so as to allow transmission of the required data during the predetermined period whilst minimising the battery energy used.

According to yet another aspect of the present invention there is provided a computer readable data carrier carrying a program as defined above. The data carrier may comprise a signal, or may comprise storage means such as a floppy

disc, a hard disc, a CD-Rom or DVD-Rom.

According to a further aspect of the present invention there is provided a computer arranged to carry out a method as defined above.

According to another aspect of the present invention there is provided a communication system comprising transmission apparatus as defined above and receiving apparatus arranged for receiving and decoding the transmitted signals.

A clock may be provided at the transmitting location and a clock may be provided at the receiving location respectively for use in encoding and decoding data. Where a periodic reference signal is transmitted this may be used to calibrate the clocks one against the other. In an example of this, if the reference signals are to be transmitted every 24 hours but the receiving clock sees the signals at 23 hours and 59 minute intervals it can be determined that the transmitter clock is running 1 minute slower in 24 hours than the receiver clock and appropriate adjustments can be made.

The above apparatus, systems and methods are particularly appropriate for use in pipeline and especially downhole communication. In such situations battery life can be low with usual transmission techniques. Further the batteries used

can be expensive and difficult or impossible to replace. Moreover the amount of data to be transmitted can be relatively low and the frequency with which data needs to be transmitted can be low, for example, once a day or even less frequently. In such cases, with more normal transmission techniques no use is made of the transmission channel for the vast majority of the time. In the present techniques maximum use of the available channel time is made by allowing the time of signalling itself to carry data.

It is in the case of downhole communication that some of the biggest benefits can be seen. The methods may be downhole battery conservation methods and the apparatus may be downhole data transmission apparatus.

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 schematically shows a downhole data communication system which can be operated in a battery conserving manner;

Figure 2 schematically shows a timing chart for signals sent in the communication system of Figure 1;

Figure 3 shows a timing chart for an alternative signalling regime, and

Figure 4 illustrates the frequency characteristics over time of a set of signals which may be used in the data transmission system shown in Figure 1.

The present invention is concerned with the conservation of battery energy when using battery power to transmit signals carrying data in a communication system. The energy conservation techniques may be used in a relatively broad set of different data communication systems. However, as mentioned in the introduction above, battery conservation is of particular interest in pipeline transmission systems and all the more so in downhole data transmission systems.

Figure 1 schematically shows one such downhole data transmission system which can be operated in such a way as to conserve battery energy as will be explained below.

In the downhole data transmission system shown in Figure 1, data is transmitted from a downhole location to the surface via the metallic structure of the well. This general type of data transmission system is currently used by the applicants and is described in detail in previous patent applications

belonging to the applicants.

The metallic structure of the well includes a production string 1 which runs from a wellhead 2 at the surface into the well and is used for extracting oil and/or gas from the well. At a location downhole, an isolation joint 3 is provided in the production string 1. This isolation joint 3 serves to electrically isolate an end portion of the production string 1 from the remainder. A downhole transmitting unit 4 is situated in the region of the isolation joint 3 and a transmitter 41 of the downhole unit 4 is connected across the isolation joint 3. The downhole unit 4 also comprises a battery pack 42, a control means 43 and a set of sensors 44. The battery pack 42 supplies power to the transmitter 41 as well as the other components.

At the surface, receiving means 5 are provided and have one terminal connected to the wellhead 2 and another connected to ground.

When signals are to be transmitted from the downhole location to the surface, the transmitter 41 applies signals across the isolation joint 3 and these travel up the production string 1, through the wellhead 2 and can be detected by the receiving means 5.

The set of sensors 44 are used to sense parameters associated with the well. These for example might be pressure and temperature. The output of the sensors 44 are connected to the control means 43.

Under the control of the control means 43, the downhole unit 4 is used to send details concerning the parameters measured by the sensors 44 on a regular basis to the surface receiving means 5.

Although not shown in Figure 1, there may be further control means, implemented for example by a computer at the surface, which serves to provide further control functions for the system. Where necessary it is possible for a surface control system to carry out processing concerning the signals to be sent and transmit instructions to the downhole control means 43 such that the transmitter 41 is controlled appropriately. Thus again, although not shown in Figure 1, transmission means may be provided at the surface and receiver means may be provided in the downhole unit 4 to allow the sending of such signals.

In the present system the data to be sent to the surface is encoded using a modulation scheme where time is used as a resource. In particular the timing of signals sent to the surface represents the data itself. Thus the actual signals sent

to the surface need not be modulated in any other way than the time at which they are transmitted.

A timing chart showing the modulation scheme used in the present embodiment is shown in Figure 2. In this case data is scheduled to be sent once a day, that is to say once every 24 hours.

This 24 hour period serves as a predetermined period during which the desired data has to be sent. A reference pulse R is sent at the start of each 24 hour period as shown in the timing chart. Within the remainder of the 24 hour period, a further pulse D, which acts as a data pulse, is sent at a time determined by the control means 43. The time at which this data pulse D is sent is chosen to represent the data which is to be sent.

In effect, the whole of the 24 hour period is quantised, that is split up into time slots each of which is associated with a different digital value. The time at which the data pulse D is sent is chosen so as to give the correct digital value.

As can be seen in Figure 2, in the first 24 hour time period, the leading edge of the data pulse D is spaced from the leading edge of the preceding reference pulse R by a time T_{1A} and is spaced from the leading edge of the subsequent

reference pulse R by a time period T_{2A}. In the present embodiment the digital value which is transmitted in the first time period is the ratio T_{1A}/T_{2A}.

Figure 2 also shows the subsequent 24 hour period in which again there is a data pulse D. The value which that pulse represents is given by T_{1B}/T_{2B}.

The pulse signals themselves can be simple sine waves of a chosen duration but may be chirps where the frequency of the pulse decreases over the duration of the pulse. Chirps may in some cases assist in determining the timing of the pulse during detection.

The duration of the pulses themselves are selected to give an adequate signal to noise ratio whilst minimising battery usage. Clearly to keep battery usage to a minimum the pulses should be as short as possible and of the lowest power possible. It is envisaged that in a downhole transmission system of the type shown in Figure 1 the reference pulses R may be three minutes in duration and the data pulses D may be two minutes in duration.

It will be noted that the reference pulses are of a different duration than the data pulses. In the regime illustrated in Figure 1 the reference pulses R are longer, having the period of 1½T, than the data pulses D having a period of T.

As T is increased the pulses will become easier to detect at the receiving means 5. The longer the pulse, the deeper into noise that pulses can be detected. It has been found by the applicants that with T at two minutes the reference and data pulses can be detected where the signal to noise ratio is -9dB's. This compares very favourably with a more normal modulation technique which has previously been used where the data is sent using phaseshift keying (PSK) and a signal to noise ratio of 6 to 9dB is the worst that could be tolerated. Moreover the total signalling time, i.e. the time which the transmitter is operating, to send a desired set of data has been reduced from 10 minutes with PSK signalling to 6 minutes with the current technique.

Because of the characteristics of the transmission channel as a whole there is a limit as to how short the pulses can be and how accurately their timing can be resolved. This effectively places a limit on the amount of data which can be transmitted during a 24 hour period when relying on the timing of the data pulse D to convey all of this data.

However, the amount of data which can be transmitted using the timing of pulses to encode the data can be improved by transmitting more than one data pulse during the predetermined period.

Figure 3 illustrates a timing chart for a system where two data pulses D are transmitted during the predetermined 24 hour period. Here two digital values can be considered by taking the ratios T_1/ T_2 and T_1/ T_3.

It has been found by the applicants that in a practical downhole system 40 bits of data can be transmitted during a 24 hour predetermined period if two data pulses D of two minute length are used.

In this practical system the timing of the pulses was determined using a matching technique where the incoming signal was correlated with a model expected signal.

In some situations there may be more than one downhole unit 4 which needs to transmit information along the same piece of metallic structure, or indeed in more general terms, there may be more than one set of data that needs to be transmitted along a single communication channel during any one predetermined period. This can be facilitated by associating a different frequency range of signals to each set of data, for example, to each downhole unit 4.

Figure 4 illustrates how different frequency range chirps might be allocated. In

Figure 4, four different chirps are shown each of which decreases in frequency over time but each of which starts at a different frequency. Using a correlation technique of the type mentioned above it is possible to distinguish between such signals.

The control means 43 includes a clock which is used for generating the pulses at the correct time intervals. Similarly at the receiving unit 5 there is a corresponding clock which is used in the timing of the received signals in order to extract the desired data. It will be noted that since reference pulses R are transmitted in the present system once every 24 hours it is possible for the clocks to cross calibrate with one another. The clock of the downhole control means 43 transmits reference pulses at what it considers to be precisely 24 hour intervals. These will be detected at the receiving means 5 and where according to the receiving means 5 clock, the intervals are not precisely 24 hours the discrepancy can be detected and corrected for.

In a simple implementation a preset number of pulses, a preset length of pulses and a preset power of pulses can be used, as well as a preset quantisation of the predetermined time period. In more sophisticated systems the above parameters can be chosen so as to optimise the system. In particular, the objective is always to transmit the necessary data whilst using the minimum

battery energy. Therefore, if the amount of data which needs to be transmitted is determined as well as the characteristics of the transmission channel available, the parameters above can be selected to meet this objective. In some cases this may be done once only as the system is set up in any particular installation. In yet more sophisticated systems, the parameters may be dynamically chosen by an appropriately programmed computer so as to optimise the system each time that the amount of data to be transmitted varies and/or the quality of the transmission channel varies. As alluded to above a computer for performing these functions may be located at the surface and appropriate instructions sent to the downhole control means so that signals are sent using the correct regime.

The battery conservation methods and apparatus implementing the methods may be used in conjunction with many different physical signalling techniques. For example, as well as electrical or electromagnetic signalling the same principles and methods may be used in respect of acoustics, for example underwater acoustic signalling. The conservation advantages are given by the modulation technique and are independent of the physical layer of the communication system.